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Dynamical Supersymmetry Breaking in Vector-like Gauge Theories

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ABSTRACT

We provide vector-like gauge theories which break supersymmetry dynamically.

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There is a piece of folklore which holds that vector-like gauge theories cannot break supersymmetry dynamically. In this letter, we point out remarkable exceptions to this piece of folklore.

Let us consider a supersymmetric $SU(2)$ gauge theory with four doublet chiral superfields Q_i . We also introduce six singlet chiral superfields $Z^{ij} = -Z^{ji}$. Here i and j denote the flavor indices ($i, j = 1, \dots, 4$).

The tree-level superpotential of our model is given by[†]

$$W_{tree} = \lambda_{ij}^{kl} Z^{ij} Q_k Q_l, \quad (1)$$

where λ_{ij}^{kl} denote generic coupling constants with $\lambda_{ij}^{kl} = -\lambda_{ji}^{kl} = -\lambda_{ij}^{lk}$. The peculiarity of this superpotential resides in that it raises all the D -flat directions in the doublets Q_i , which is a necessary condition for supersymmetry to break down.^[1] Of course, supersymmetry remains unbroken perturbatively in this model.

The exact effective superpotential of the model, which takes into account the full nonperturbative effects, may be written in terms of gauge-invariant low-energy degrees of freedom^[2]

$$V_{ij} = -V_{ji} \sim Q_i Q_j \quad (2)$$

as follows:

$$W_{eff} = X(\text{Pf}V_{ij} - \Lambda^4) + \lambda_{ij}^{kl} Z^{ij} V_{kl}, \quad (3)$$

where X is an additional chiral superfield, $\text{Pf}V_{ij}$ denotes the Pfaffian of the antisymmetric matrix V_{ij} , and Λ is a dynamical scale of the $SU(2)$ gauge interaction.^[2,3]

[†] This tree-level superpotential is natural since it possesses two global symmetries. One is an axial $U(1)$ symmetry associated with a Q_i phase transformation and the other is an anomaly-free R symmetry.

This is none other than a superpotential of the O’Raifeartaigh type.^[4] Namely, this effective superpotential yields conditions for supersymmetric vacua

$$\text{Pf}V_{ij} = \Lambda^4, \quad \lambda_{ij}^{kl}V_{kl} = 0, \quad (4)$$

which cannot be satisfied simultaneously as far as $\Lambda \neq 0$. Therefore we conclude that supersymmetry is dynamically broken in our model.

We note that this conclusion is not in contradiction with the index argument.^[5] The doublets Q_i cannot be decoupled by means of mass terms $m^{ij}Q_iQ_j$ since the apparent masses may be absorbed in the shifts of the singlets Z^{ij} .

It is straightforward to generalize the above model to an $\text{Sp}(N)$ gauge theory^[6] with $2(N+1)$ chiral superfields in the $2N$ representation. Here we adopt a notation $\text{Sp}(1) = \text{SU}(2)$.

These vector-like models might serve as a supersymmetry-breaking mechanism in the hidden^[7] or visible sector.

REFERENCES

1. I. Affleck, M. Dine, and N. Seiberg, *Nucl. Phys.* **B256** (1985) 557.
2. N. Seiberg, *Phys. Rev.* **D49** (1994) 6857.
3. N. Seiberg, *Phys. Lett.* **B318** (1993) 469;
K. Intriligator and N. Seiberg, hep-th/9509066;
Izawa K.-I., *Prog. Theor. Phys.* **95** (1996) 199.
4. P. Fayet, *Phys. Lett.* **B58** (1975) 67;
L. O’Raifeartaigh, *Nucl. Phys.* **B96** (1975) 331.
5. E. Witten, *Nucl. Phys.* **B202** (1982) 253.
6. K. Intriligator and P. Pouliot, *Phys. Lett.* **B353** (1995) 471.
7. Izawa K.-I. and T. Yanagida, *Prog. Theor. Phys.* **94** (1995) 1105.